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Tracking the SeaWiFS record with a coupled physical/biogeochemical/radiative model of the global oceans

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Abstract

The Sea-Viewing Wide Field-of-view Sensor (SeaWiFS) has observed multiple years of routine global chlorophyll observations from space. The mission was launched into a record El Niño event, which eventually gave way to one of the most intense and longest-lasting La Niña events ever recorded. The SeaWiFS chlorophyll record captured the response of ocean phytoplankton to these significant events in the tropical Indo-Pacific basins, but also indicated significant interannual variability unrelated to the El Niño/La Niña events. This included large variability in the North Atlantic and Pacific basins, in the North Central and equatorial Atlantic, and milder patterns in the North Central Pacific.

This SeaWiFS record was tracked with a coupled physical/biogeochemical/radiative model of the global oceans using near-real-time forcing data such as wind stresses, sea surface temperatures, and sea ice. This provided an opportunity to offer physically and biogeochemically meaningful explanations of the variability observed in the SeaWiFS data set, since the causal mechanisms and interrelationships of the model are completely understood.

The coupled model was able to represent the seasonal distributions of chlorophyll during the SeaWiFS era, and was capable of differentiating among the widely different processes and dynamics occurring in the global oceans. The model was also reasonably successful in representing the interannual signal, especially when it was large, such as the El Niño and La Niña events in the tropical Pacific and Indian Oceans. The model provided different phytoplankton group responses for the different events in these regions: diatoms were predominant in the tropical Pacific during the La Niña, but other groups were predominant during El Niño. The opposite condition occurred in the tropical Indian Ocean. Both situations were due to the different responses of the basins to El Niño. Interannual variability in the North Pacific was exhibited as an increase in the spring bloom in 1999 and 2000 relative to 1998. This resulted in the model from a shallower and more rapidly shoaling mixed layer, producing more average irradiance in the water column and preventing herbivore populations to keep pace with increasing phytoplankton populations. However, several aspects of the interannual cycle were not well-represented by the model. Explanations range from inherent model deficiencies, to monthly averaging of forcing fields, to biases in SeaWiFS atmospheric correction procedures.

1. Introduction

The Sea-Viewing Wide Field-of-view Sensor (SeaWiFS; McClain et al., 1998) has provided the first multi-year global chlorophyll observations from space since the Coastal Zone Color Scanner (CZCS). It represents an unprecedented data set in terms of coverage, continuity, and duration that enables us for the first time to make meaningful observations about the state of biological components in the global oceans, their spatial variability, and their medium-term (seasonal to interannual) variability. This latter point especially differentiates SeaWiFS from the two previous large-scale-coverage missions, the CZCS, which did not provide routine global coverage in its 8-year lifetime (Feldman et al., 1989), and the Ocean Color and Temperature Scanner (OCTS), which failed after nine months of on-orbit operations (Shimoda, 1999).

The comprehensive SeaWiFS data set, beginning in September 1997, provides an opportunity to observe the behavior of ocean phytoplankton in response to seasonal and interannual variability. If analysis of this record is combined with the outputs of a coupled physical/biogeochemical model whose dynamical features are completely understood, then insights may be gained into the causes of this variability, especially when the results are in agreement. Even when they are not, this combination of analysis methodologies can help us infer what processes are not incorporated into the model and their apparent importance.

4. Conclusions

The nearly 3-year SeaWiFS record from launch (September 1997) to June 2000 has given us our first comprehensive glimpse of interannual variability of ocean chlorophyll dynamics. Moreover, SeaWiFS was launched as one of the largest El Niño events was underway, and which eventually gave way to one of the largest, most intensive, and longest-lasting La Niña events ever recorded (continuing at the end of the record). The SeaWiFS chlorophyll record captured the response of ocean phytoplankton to these significant events in the tropical Indo-Pacific basins, but also indicated significant interannual variability unrelated to the El Niño/La Niña. This included large variability in the North Atlantic and Pacific basins, large variability in the North Central and equatorial Atlantic, and milder patterns in the North Central Pacific, the latter of which may be due partially to the El Niño. The Southern Hemisphere exhibited, in contrast, relatively little interannual variability during the SeaWiFS record.

We are fortunate to live in an era when global atmospheric data sets are routinely and nearly immediately available. Thus we have the opportunity to drive a coupled physical/biogeochemical/radiative model of the global oceans with actual near-real-time forcing data such as wind stresses, SSTs, shortwave radiation, and sea ice. Our only limitation is cloud cover and thickness data, which are necessary to evaluate the spectral irradiance with depth, which drives phytoplankton dynamics. Although this is a shortcoming, the availability of the other forcing data gives us an opportunity to track the SeaWiFS record with a global coupled model and attempt to provide physically and biogeochemically meaningful explanations of the variability observed in the SeaWiFS data set.

Even without cloud data, the coupled model was able to represent the seasonal distributions of chlorophyll during the SeaWiFS era, and was capable of differentiating among the widely different processes and dynamics occurring in the global oceans. The model was also reasonably successful in representing the interannual signal, especially when it was large, such as the El Niño and La Niña events in the tropical Pacific and Indian Oceans. In these two regions the model provided different phytoplankton group responses for the different events. The interannual variability in the North Pacific, which was exhibited in SeaWiFS data as an increase in the spring bloom in 1999 and 2000 relative to 1998, was represented and resulted in the model from a more rapidly shoaling mixed layer, inhibiting herbivore population development, thus preventing maximum and immediate utilization of available nutrients from winter convection. However, several aspects of the interannual cycle were not well-represented by the model. Some of which may be due to the model deficiencies of a lack of topographic and coastal influences such as the North Indian Ocean, some may be related to the lack of monthly cloud data, some may be due to riverine influences missing in the model such as the equatorial Atlantic, and finally some may be the result of biases in SeaWiFS atmospheric correction procedures such as absorbing aerosols which are common in the equatorial and mid-latitude eastern Atlantic and the North and equatorial Indian Oceans. Nevertheless, broad agreement suggests confidence in the large scale (synoptic and basin scale) processes in the model and its ability to provide plausible explanations for some the variability observed in this unique spaceborne data set.